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Abstract

Background
Because blood pressure (BP) tracks from childhood to adulthood, assessing levels in youth is relevant. There are no recent BP data for Canadian children and adolescents, and past studies have used a variety of design and measurement devices.

Data and methods
With a clinically validated oscillometric device, resting BP was measured in 2,079 respondents aged 6 to 19 years from the Canadian Health Measures Survey. The average of the last five of six BP measures taken one minute apart at a single visit was used in this report. Borderline or elevated BP was defined as greater than or equal to the 90th percentile of US reference values for participants aged 6 to 17 years. Borderline or elevated BP for 18- to 19-year-olds was defined as equal to or greater than 120 systolic BP or equal to or greater than 80 diastolic BP. Participants of any age who reported taking antihypertensive medication in the past month were also defined as having elevated BP.

Results
At ages 6 to 11 years, mean (standard error) systolic/diastolic blood pressure was 93(0)/61(1) in boys and 93(0)/60(0) mmHg in girls, and at ages 12 to 19 years, 101(1)/63(1) and 98(1)/63(1) mmHg, respectively. An estimated 2.1% (95% confidence interval 1.3% to 3.0%) of Canadian children and youth had borderline levels, 0.8% (0.4% to 1.4%) had elevated BP.

Interpretation
Despite the prevalence of obesity among young people, BP levels were lower than reported in provincial samples, which may, in part, reflect differences in methodologies and measurement instruments.

Keywords
diastolic pressure, hypertension, obesity, overweight, survey, systolic pressure

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No nationally representative blood pressure (BP) data for Canadian children and adolescents have been collected since the 1978 Canada Health Survey.[1] With the results of the 2007-2009 Canadian Health Measures Survey (CHMS), launched by Statistics Canada in partnership with Health Canada and the Public Health Agency of Canada, it is possible to address this data gap.[2-5] The CHMS is the most comprehensive direct health measures survey ever conducted in Canada. In addition to a detailed health interview, the survey involves direct measurement of indicators and of risk factors for chronic diseases, infectious diseases, environmental exposures, nutritional status, physical activity and physical fitness.[2-5]

Elevated BP is one of the most important causes of death and disability worldwide,[6] accounting for 7.6 million premature deaths and 92 million disability-adjusted life years annually. In adolescence, hypertension is associated with increased left ventricular mass, diastolic dysfunction,[7] fatty streaks and fibrous plaques in the coronary arteries and the aorta,[8] and arterial wall thickening.[9] BP levels track from childhood to adulthood,[10,11] indicating that elevated BP at young ages is a risk factor for the development of hypertension in adulthood. The strength of BP tracking increases with body mass index (BMI), such that tracking is strongest in overweight and obese youth.[12,13]

Population information about BP levels in children and adolescents can be useful from a public health and clinical perspective to guide prevention planning, help establish norms, and monitor trends over time. However, Quebec is the only Canadian province to have relatively recent measures for youth: in 1999, 12% to 23% of youth aged 9, 13 and 16 years had high-normal or elevated

BP.[9] A 2004 study of BP levels among American youth found that from 1988-1994 to 1999-2000, mean systolic blood pressure (SBP) increased 1.4 mmHg, and mean diastolic blood pressure (DBP) increased 3.3 mmHg.[15] A longer-term review of trends in American youth from 1963 to 2002 also demonstrated a slight upturn in the prevalence of elevated BP in the last decade.[16] But such findings have not been consistent. For example, a study of 15-year-old Russian adolescents between 1995 and 2004 found a significant decrease in DBP among boys, and a significant decrease in SBP among both sexes.[17] As well, comparisons of results from past studies are complicated by different survey methods, including different measurement devices.

Based on data from the 2007-2009 CHMS, this study presents BP distributions and estimates of elevated BP for a representative sample of Canadian children and adolescents aged 6 to 19 years.

Methods

Data source

Data are from cycle 1 of the Canadian Health Measures Survey (CHMS), which collected information at 15 sites from March 2007 through February 2009. The CHMS covered the population aged 6 to 79 years living in private households. Residents of Indian Reserves or Crown lands, institutions and certain remote regions and full-time members of the regular Canadian Forces were excluded. Approximately 96.3% of Canadians were represented.[18]

Health Canada's Research Ethics Board gave ethics approval to conduct the survey. Informed written consent was obtained from respondents aged 14 years or older. For younger children, a parent or legal guardian provided written consent, in addition to written assent from the child. Participation was voluntary; respondents could opt out of any part of the survey at any time.

The response rate for households selected for inclusion in the CHMS was 69.6%—meaning that in 69.6% of selected households, the sex and date of birth of all household members were provided by a household resident. In each responding household, one or two members were chosen to participate; 88.5% of selected 6- to 19-year-olds completed the household questionnaire, and 86.9% of those who completed the questionnaire participated in the subsequent examination centre component. The final response rate for 6- to 19-year-olds, after adjusting for the sampling strategy, was 53.5%. This article is based on 2,079 examination centre respondents aged 6 to 19 years (after removing 8 with missing BP data) (Appendix Table A).

Measures

At the respondent's home, an interviewer administered a questionnaire covering socio-demographic characteristics, medical history, current health status and lifestyle behaviours (Table 1). In the chronic conditions component of the questionnaire, respondents aged 12 years or older were asked if they had high BP (diagnosed by a health professional and expected to last or had already lasted six months or more) and if they had taken "medicine for high blood pressure" in the past month.

One day to six weeks after the home interview, the respondent visited a mobile examination centre for a battery of physical measurements, including anthropometry, BP, heart rate, spirometry, physical fitness, oral health and biospecimen collection.[4] BMI was calculated as weight in kilograms divided by height in meters squared (kg/m^2), and respondents were classified as overweight, obese, or neither.[19,20] BP was measured after urine collection, but before blood collection and fitness testing.[4]

BP and heart rate were measured with the BpTRU™ BP-300 (BpTRU Medical Devices Ltd., Coquitlam, British Columbia). The BpTRU™, an automated electronic monitor, automatically inflates and deflates the upper-arm cuff and uses an oscillometric technique to calculate SBP and DBP. It has passed international validation protocols for accuracy.[21,22]

An advantage of an automated device is that it enables BP to be measured in the absence of another person, thereby eliminating observer errors such as digit bias, zero preference and incorrect deflation rates, and reducing "white-coat hypertension" (a rise in BP associated with the presence of the health care professional and the measurement procedures).[23] For more detailed information on the procedures and protocol, including staff training, equipment calibration, and quality assurance and control, see *Resting blood pressure and heart rate measurement in the Canadian Health Measures Survey cycle 1*.[24]

Definitions

Measures of SBP and DBP were calculated as the average of the first set (last five of six measures taken one minute apart) of valid BP measurements.[24] For those aged 6 to 17 years, based on age and sex, each respondent's height and average SBP and DBP were converted to *z*-scores, which were used to calculate individual BP percentiles as per the equations in Appendix B of the fourth report of the National High Blood Pressure Education Program Working Group on High Blood Pressure in Children and Adolescents (NHBPEP4).[25] With these calculated percentiles, children and youth in this age group were classified into BP categories. As well, respondents who reported taking medicine for high BP in the past month were classified as having "elevated" BP, regardless of their BP percentile value (fewer than 10 respondents). The seventh report of the Joint National Committee on Prevention, Detection, Evaluation and Treatment of High Blood Pressure (JNC7) was used to classify youth aged 18 or 19 years.[26] The NHBPEP4 classification parallels that of the JNC7.

Normal BP for respondents aged 6 to 17 years was defined as a calculated SBP percentile and DBP percentile less than the 90th percentile. For respondents

aged 18 or 19 years, it was defined as a measured mean SBP less than 120 mmHg and a measured mean DBP less than 80 mmHg. This corresponds to the "normal" category proposed by the NHBPEP4 and JNC7.

Borderline BP for respondents aged 6 to 17 years was defined as a calculated SBP percentile or DBP percentile greater than or equal to the 90th percentile, but less than the 95th percentile, or a measured SBP/DBP greater than 120/80 mmHg, even if less than the 90th percentile. For respondents aged 18 or 19 years, it was defined as a measured mean SBP of 120 to 139 mmHg and a measured mean DBP of 80 to 89 mmHg; or SBP of 120 to 139 mmHg and DBP lower than 80 mmHg; or SBP lower than 120 mmHg and DBP 80 to 89 mmHg. This corresponds to the "prehypertension" category proposed by the NHBPEP4 and JNC7.

Elevated BP for respondents aged 6 to 17 years was defined as a calculated SBP percentile or DBP percentile greater than or equal to the 95th percentile, or the respondent's report of using BP medication in the past month. For respondents aged 18 or 19 years, elevated BP was defined as a measured mean SBP/DBP of 140/90 mm Hg or higher, or the respondent's report of BP medication use in the past month. This corresponds to the "Stage 1 or Stage 2 hypertension" category proposed by the NHBPEP4 and JNC7.

Analytical techniques

Weighted data were analyzed separately by sex and age. Estimates of proportions, means, standard errors, and percentiles were produced. Standard errors, coefficients of variation and 95% confidence intervals (CI) were estimated using bootstrap weights to account for the complex survey design of the CHMS.[27,28] Gender differences in SBP and DBP were tested using t-tests. Analyses were conducted with SUDAAN.

Results

Mean SBP (standard error) rose with age from 91(1) mmHg among boys aged 6 to 7 years to 104(1) mmHg at 18 to 19 years; for girls, the increase was from 92(1) to 99(1) mmHg (Table 2). Mean SBP was similar in boys and girls from ages 6 to 7 through 10 to 11 years, and also at 14 to 15 years. However, at 12 to 13 years and 16 through 19 years, mean SBP was higher in boys ($p<0.01$). Median SBP was very close to the mean in all age/sex categories.

The sample size was too small to obtain percentile values by single-year-of-age or 95th percentile values for most two-year age groups. At ages 6 to 11 years, the 95th percentile (95% CI) for SBP was 105 (102 to 107) mmHg among boys and 106 (104 to 108) mmHg among girls; at ages 12 to 19 years, the 95th percentile for SBP was 116 (113 to 119) mmHg among boys and 111 (108 to 114) mmHg among girls.

Mean DBP also rose with age, but not as much as SBP (Table 3). From ages 6 to 7 to 18 to 19 years, mean DBP increased from 59(1) to 65(1) mmHg among boys and from 60(1) to 64(1) among girls. Mean DBP was similar in both sexes. Median DBP was very close to the mean in all age/sex groups.

In 2007-2009, few Canadian children and adolescents had borderline or elevated BP: 3.7% (2.3% to 6.0%) at ages 6 to 11 years and 2.2% (1.2% to 4.0%) at 12 to 19 years (Table 4).

Mean SBP was higher among children and adolescents who were overweight or

Table 1
Selected characteristics of sample (weighted), by age group and sex, household population aged 6 to 19 years, Canada, March 2007 to February 2009

	Age group (years)											
	6 to 11						12 to 19					
		95% confidence interval			95% confidence interval			95% confidence interval			95% confidence interval	
	Boys	from	to	Girls	from	to	Boys	from	to	Girls	from	to
Mean age (years)	8.6	8.2	9.0	8.7	8.5	8.9	15.2	15.0	15.5	15.7	15.5	16.0
Measured body mass index (kg/m²)	17.9	17.5	18.2	17.7	17.2	18.1	22.6	21.6	23.6	22.4	21.7	23.0
Overweight[†] (%)	17.3	13.5	21.9	16.3	11.6	22.4	18.0	14.6	21.9	17.6	13.5	22.7
Obese[†] (%)	7.1	5.1	9.8	5.8[E]	3.2	10.1	12.3	6.6	21.7	8.3	5.8	11.6
Smoke daily (%)	..	..	..	..	..	..	8.0[E]	4.0	15.2	6.8[E]	3.3	13.4
Physically active[††] (%)	84.5	80.8	87.6	82.5	79.0	85.6	77.4	69.3	83.9	65.0	59.5	70.2
Immediate family history of high blood pressure (%)	12.6	8.8	17.7	15.9	12.0	20.8	25.8	20.3	32.2	22.1	16.3	29.3
Household education more than secondary graduation (%)	88.5	84.6	91.5	85.3	79.1	89.9	86.6	83.4	89.2	83.0	74.2	89.2
Household type - couple with children (%)	82.6	77.1	87.1	79.4	72.9	84.6	72.5	65.7	78.4	76.3	68.5	82.7
Low household income[†††] (%)	7.7[E]	4.4	12.9	6.5[E]	3.8	11.1	5.4[E]	3.0	9.6	11.2[E]	7.1	17.2
Born in Canada (%)	92.4	81.8	97.0	92.0	81.8	96.7	90.5	77.5	96.4	88.3	80.2	93.3

† 18- to 19-year-olds classified as overweight (BMI 25 to 29.9 kg/m²) or obese (BMI 30 kg/m² or more)(Source: Health Canada. *Canadian Guidelines for Body Weight Classification in Adults* (Catalogue H49-179) Ottawa: Health Canada, 2003); 6- to 17-year-olds classified as overweight or obese based on definitions proposed by International Obesity Task Force (Source: Cole TJ, Bellizzi MC, Flegal KM, et al. Establishing a standard definition for child overweight and obesity worldwide: international survey. *British Medical Journal* 2000; 320(7244): 1240-3)

†† for ages 6 to 11, physically active for at least 60 minutes 4 or more days in typical week; for ages 12 to 19, categorized as "active"or "moderately active according to Physical Activity Index

††† based on household size and income range; denominator is 1,920 respondents with valid household income value

E interpret with caution (coefficient of variation 16.6% to 33.3%)

.. not applicable

Source: 2007 to 2009 Canadian Health Measures Survey

Table 2
Percentile distribution of measured systolic blood pressure (SBP) (mmHg) values, by sex and two-year age group, household population aged 6 to 19 years, Canada, March 2007 to February 2009

Sex and two-year age group (years)	Sample size	Mean	Standard error	25th percentile			50th percentile			75th percentile			90th percentile			95th percentile		
				Value	95% confidence interval from	to	Value	95% confidence interval from	to	Value	95% confidence interval from	to	Value	95% confidence interval from	to	Value	95% confidence interval from	to
Boys	**1,051**	**98**	**1**	**91**	**90**	**92**	**96**	**95**	**98**	**103**	**101**	**106**	**110**	**107**	**113**	**114**	**112**	**116**
6 to 11	**538**	**93**	**0**	**88**	**87**	**89**	**92**	**91**	**93**	**97**	**95**	**99**	**101**	**99**	**103**	**105**	**102**	**107**
6-7	164	91	1	85	84	87	90	89	92	94	92	97	99	95	103	F	..	..
8-9	172	93	1	88	87	90	91	90	93	96	95	98	101	98	104	F	..	..
10-11	202	95	1	90	88	92	94	93	96	98	97	100	103	99	106	105	103	108
12 to 19	**513**	**101**	**1**	**94**	**92**	**96**	**100**	**97**	**103**	**106**	**103**	**109**	**113**	**110**	**116**	**116**	**113**	**119**
12-13	160	97	1	90	88	91	96	92	100	103	100	107	109	105	114	F	..	..
14-15	119	100	1	93	91	96	98	94	103	105	99	112	112	107	118	F	..	..
16-17	139	104	2	97	94	100	102	99	106	107	102	111	116	109	123	F	..	..
18-19	95	104	1	97	95	100	103	99	107	109	105	114	F	..	..	F	..	..
Girls	**1,028**	**96**	**0**	**90**	**89**	**91**	**95**	**94**	**96**	**100**	**99**	**101**	**106**	**104**	**108**	**109**	**108**	**111**
6 to 11	**529**	**93**	**0**	**87**	**86**	**88**	**92**	**91**	**94**	**98**	**97**	**99**	**103**	**102**	**104**	**106**	**104**	**108**
6-7	159	92	1	86	84	88	90	87	93	96	92	100	102	98	106	F	..	..
8-9	157	94	1	88	85	91	93	91	95	98	97	100	104	100	108	F	..	..
10-11	213	94	1	88	87	89	94	91	96	99	97	101	103	100	105	105	103	107
12 to 19	**499**	**98**	**1**	**92**	**90**	**94**	**96**	**95**	**98**	**102**	**100**	**103**	**108**	**106**	**110**	**111**	**108**	**114**
12-13	132	94	1	90	88	91	94	91	96	97	94	100	101	98	104	F	..	..
14-15	126	99	1	94	92	96	97	94	100	103	98	107	109	103	114	F	..	..
16-17	127	98	1	93	91	96	97	95	99	101	99	103	109	105	113	F	..	..
18-19	114	99	1	93	89	97	98	95	102	104	101	106	109	106	113	F	..	..

F too unreliable to be reported (coefficient of variation greater than 33% or small sample size)
.. not applicable
Source: 2007 to 2009 Canadian Health Measures Survey

Table 3
Percentile distribution of measured diastolic blood pressure (DBP) (mmHg) values, by sex and two-year age group, household population aged 6 to 19 years, Canada, March 2007 to February 2009

Sex and two-year age group (years)	Sample size	Mean	Standard error	25th percentile			50th percentile			75th percentile			90th percentile			95th percentile		
				Value	95% confidence interval from	to	Value	95% confidence interval from	to	Value	95% confidence interval from	to	Value	95% confidence interval from	to	Value	95% confidence interval from	to
Boys	**1,051**	**62**	**1**	**57**	**55**	**58**	**61**	**60**	**63**	**66**	**65**	**68**	**71**	**69**	**72**	**74**	**72**	**76**
6 to 11	**538**	**61**	**1**	**56**	**55**	**57**	**60**	**58**	**61**	**64**	**62**	**65**	**68**	**66**	**71**	**72**	**68**	**75**
6-7	164	59	1	53	48	58	58	56	60	63	60	65	69	64	74	F	..	..
8-9	172	61	1	57	55	58	60	58	62	63	61	66	69	65	73	F	..	..
10-11	202	61	0	57	55	58	61	60	62	65	63	66	68	66	69	71	67	74
12 to 19	**513**	**63**	**1**	**57**	**56**	**59**	**63**	**61**	**65**	**67**	**65**	**69**	**72**	**70**	**74**	**76**	**73**	**79**
12-13	160	62	1	57	56	58	61	59	63	65	63	66	69	66	71	F	..	..
14-15	119	62	1	55	51	58	62	59	66	68	64	71	73	69	78	F	..	..
16-17	139	64	1	58	56	60	63	60	66	68	66	71	73	70	76	F	..	..
18-19	95	65	1	60	56	64	64	62	67	69	66	73	F	..	..	F	..	..
Girls	**1,028**	**62**	**0**	**56**	**55**	**57**	**61**	**60**	**62**	**66**	**65**	**68**	**71**	**70**	**72**	**74**	**73**	**75**
6 to 11	**529**	**60**	**0**	**55**	**53**	**56**	**60**	**59**	**61**	**65**	**63**	**66**	**70**	**69**	**70**	**72**	**70**	**74**
6-7	159	60	1	54	51	57	59	56	62	64	61	66	69	65	74	F	..	..
8-9	157	61	1	55	51	59	61	60	62	65	62	68	70	68	72	F	..	..
10-11	213	60	1	55	52	57	60	58	62	65	63	66	68	67	70	70	68	72
12 to 19	**499**	**63**	**1**	**57**	**55**	**58**	**62**	**60**	**64**	**67**	**65**	**69**	**72**	**70**	**73**	**74**	**73**	**75**
12-13	132	60	1	54	53	56	59	57	62	65	63	67	67	66	68	F	..	..
14-15	126	63	1	57	56	59	62	60	64	68	64	72	74	70	79	F	..	..
16-17	127	64	1	59	57	61	63	59	66	69	66	71	71	70	73	F	..	..
18-19	114	64	1	57	53	60	64	61	67	68	67	70	73	72	75	F	..	..

F too unreliable to be reported (coefficient of variation greater than 33% or small sample size)
.. not applicable
Source: 2007 to 2009 Canadian Health Measures Survey

Table 4
Percentage distribution of measured blood pressure status, by sex and age group, household population aged 6 to 19 years, Canada, March 2007 to February 2009

	Sample size	%	95% confidence interval from	to
Total				
Normal	2,019	97.2	96.1	98.0
Borderline	47	2.1[E]	1.3	3.1
Elevated	13	0.8[E]	0.4	1.4
Boys				
Normal	1,019	96.9	95.7	97.7
Borderline or elevated	32	3.1	2.3	4.3
Girls				
Normal	1,000	97.6	95.9	98.6
Borderline or elevated	28	2.4[E]	1.4	4.1
6 to 11 years				
Normal	1,029	96.3	94.0	97.7
Borderline or elevated	38	3.7[E]	2.3	6.0
12 to 19 years				
Normal	990	97.8	96.0	98.8
Borderline or elevated	22	2.2[E]	1.2	4.0

[E] interpret with caution (coefficient of variation 16.6% to 33.3%)

Notes: For respondents aged 6 to 17 years, blood pressure status was derived using the methodology outlined in Appendix B of The Fourth Report on the Diagnosis, Evaluation, and Treatment of High Blood Pressure in Children and Adolescents, *Pediatrics* 2004, for respondents aged 18 to 19, the classification in the seventh report of the *Joint National Committee on Prevention, Detection, Evaluation and Treatment of High Blood Pressure* was used.

Source: 2007 to 2009 Canadian Health Measures Survey.

obese (Table 5). The SBP differences between BMI categories reached statistical significance among boys aged 12 to 19 years, girls aged 6 to 11 years, and in both age groups when the genders were combined. Differences in DBP by BMI category were less apparent, reaching statistical significance only among obese boys aged 12 to 19 years.

Discussion

The main finding of this analysis is the remarkably low overall prevalence of borderline or elevated BP among Canadian children and adolescents.

However, echoing the results of other studies,[14,15] mean SBP was significantly higher among boys aged 12 to 19 years and girls aged 6 to 11 years who were overweight or obese. Excess weight is believed to influence BP through increased sympathetic nervous system activation, which is associated with SBP. The association of weight with DBP was much less pronounced.

The generally low levels of BP obtained from the CHMS appear inconsistent with the rise of childhood and adolescent obesity in Canada.[29,30] And despite a trend toward excess weight among youth in other countries, BP levels have not shown consistent increases.[31] Hence, population-level increases in BP may not necessarily be a consequence of rising weight. More research is required to explain this apparent paradox.

For each age and sex category, mean child and adolescent SBP in Canada was about 10 mmHg lower than the most recent United States National Health and Nutrition Examination Survey (NHANES) data.[32] The only other recent BP data from a large, representative sample of youth in Canada were collected in 1999 by the Quebec Child and Adolescent Health and Social Survey (QCAHS) from respondents aged 9, 13 and 16 years.[14] Compared with the results of the QCAHS, mean SBP at these ages in the CHMS was 9, 16 and 20 mmHg lower in boys, and 8, 17 and 16 mmHg lower in girls.

CHMS values for DBP generally exceeded the NHANES results, with a mean difference of 5 mmHg higher in boys and 2 mmHg higher in girls. And compared with the QCAHS, the CHMS values were 8, 7 and 7 mmHg higher in boys aged 9, 13 and 16 years, respectively, and 9, 5 and 7 mmHg higher among girls of the same ages.[14]

Differences in measurement instruments and procedures may, in part, explain the disparities in BP levels in the three surveys. The CHMS used

Table 5
Mean measured value of systolic (SBP) (mm/Hg) and diastolic blood pressure (DBP) (mm/Hg), by age group, sex and body mass index (BMI) category, household population aged 6 to 19 years, Canada, March 2007 to February 2009

	Systolic blood pressure								Diastolic blood pressure							
	6 to 11 years				12 to 19 years				6 to 11 years				12 to 19 years			
	Sample size	Mean	95% confidence interval from	to	Sample size	Mean	95% confidence interval from	to	Sample size	Mean	95% confidence interval from	to	Sample size	Mean	95% confidence interval from	to
Total																
Neither overweight nor obese[†]	836	92	91	93	751	98	96	99	836	60	59	61	751	63	61	64
Overweight	159	97*	93	100	180	101*	99	104	159	62	58	65	180	63	61	65
Obese	71	97*	94	101	77	106*	103	109	71	62	59	65	77	65	62	68
Boys																
Neither overweight nor obese[†]	413	92	91	93	378	99	97	100	413	60	59	61	378	62	61	63
Overweight	86	97	92	102	94	104*	100	107	86	62	57	68	94	64	61	67
Obese	38	97	91	102	40	108*	104	112	38	63	58	68	40	66*	63	70
Girls																
Neither overweight nor obese[†]	423	92	91	93	373	97	95	98	423	60	59	61	373	63	61	65
Overweight	73	97*	94	99	86	99	96	102	73	61	58	63	86	63	60	65
Obese	33	98*	95	101	37	103	98	107	33	61	58	64	37	64	60	68

[†] reference category

* significantly different from reference category p< 025 (Bonferroni corrected)

Notes: BMI categories for ages 6 to 17 are based on the Cole cut-points. BMI categories for ages 18 and 19 years are based on the World Health Organization cut-points.

Source: 2007-2009 Canadian Health Measures Survey.

the BpTRU™ device; QCAHS used the DINAMAP (Critikon Co, FL) device; and NHANES used mercury sphygmomanometers. The last has been the gold standard for BP assessment for many years, but its use in children is decreasing because mercury-containing instruments are being removed from pediatric environments, and because auscultatory methods are subject to various biases (digit preference, rounding, white coat hypertension, etc.). The substantial differences between the CHMS and QCAHS may be due to opposing systematic differences between BP measured by mercury manometers and by the DINAMAP and the BpTRU. The DINAMAP has been reported to overestimate SBP by about 10 mmHg and slightly underestimate DBP, whereas the BpTRU may slightly underestimate DBP (by 2.1 mmHg), compared with the mercury manometer.[33] Most cases of borderline or elevated BP among CHMS participants had diastolic rather than systolic elevation, whereas clinically, most reported cases of pediatric hypertension are the result of an increase in SBP, thought to reflect, at least in part, hyperactivity of the sympathetic nervous system. Counterintuitively, children aged 6 to 11 years were somewhat more likely to have borderline or elevated BP than were adolescents aged 12 to 19 years.

The CHMS procedures may also have contributed to lower mean SBP. Measurement in a quiet room and in the absence of staff may have been conducive to maximal subject relaxation, which could decrease sympathetic activation and lower SBP. By contrast, the QCAHS measurements took place in school settings, usually a room where other survey-related measures were going on and in the presence of a staff member recording BP readings.[14,34]

Limitations

The overall CHMS response rate was slightly above 50%. Although survey weights were adjusted to the socio-demographic characteristics of the Canadian population, it was not possible to adjust for many factors that could be associated with BP levels. Selection bias would be present if the BP levels of non-participants differed systematically from those of participants. In addition, the logistical and cost constraints associated with the use of mobile examination centres restricted the number of collection sites to 15.[18] Whether this sampling strategy affected the results is unknown.

Conclusion

A small percentage of Canadians aged 6 to 19 years have borderline or elevated BP. More research is required to improve our understanding of BP levels and their determinants in order to help maintain healthy levels over the life-course.

What is already known on this subject?

- Elevated blood pressure (BP) is an important cause of disability and death worldwide.
- Elevated BP at young ages is a risk factor for the development of hypertension in adulthood.
- The strength of BP tracking increases with body mass index.
- No nationally representative BP data for Canadian children and adolescents have been collected since the 1978 Canada Health Survey.

What does this study add?

- Based on data from the 2007-2009 Canadian Health Measures Survey, an estimated 0.8% of Canadians aged 6 to 19 had elevated BP, and 2.1% had borderline levels.
- The differences in mean systolic BP between BMI categories reached statistical significance among boys aged 12 to 19 years, girls aged 6 to 11 years, and in both age groups when the genders were combined.
- Differences in mean diastolic BP by BMI category reached statistical significance only among obese boys aged 12 to 19 years.

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Appendix

Table A
Sample sizes for selected characteristics, by sex and age group, household population aged 6 to 19 years, Canada, March 2007 to February 2009

	Age group (years)			
	6 to 11		12 to 19	
	Boys	Girls	Boys	Girls
Blood pressure status	538	529	513	499
Measured body mass index (kg/m^2)	537	529	512	496
Current smoking	..	..	507	497
Physical activity	538	528	507	497
Immediate family history of high blood pressure	530	518	481	470
Household education	524	518	498	483
Household type	538	529	513	499
Household income	524	513	457	426
Country of birth	538	529	513	499

.. not applicable
Source: 2007-2009 Canadian Health Measures Survey